PERFORMANCE EVALUATION OF MOBILE STRAW BALER

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ABSTRACT

Wheat bhoosa (chopped wheat straw) is an important component of stockfeed in Pakistan. The improper storage conditions of bhoosa in mud plaster structure adversely affect the quality. The transportation of bhoosa from field to storage place is cumbersome and costly. The baling of bhoosa in the field makes its handling and transportation much easier and cost effective with minimum loss of the product. A power take off operated mobile straw baler was developed at Agricultural Mechanization Research Institute, Multan, Pakistan during the year to make bales of straw in the field. It can be operated by a 36.75 kW (50 hp) tractor, or a 14.7 kW (20 hp) diesel engine or a 14 kW electric motor. It has the capacity to make a bale of 34.6 kg with an overall dimensions of 391 x 457.13 x 635 mm. It requires 4.3 minutes and 17 men-minutes to prepare one bale. The baler can be used for other crop residues such as cotton sticks, corn stover and sugarcane chuff. The baler has an outputs of 20, 16, 18 and 16 bales per hour for bhoosa, cotton sticks, corn stovers and sugarcane chuff, respectively. The capital cost of baler is Rs. 0.35 million with an operating cost of Rs. 17, 10 and 38 when operated with diesel engine, electric motor and tractor, respectively. Its commercial production has been started by a local manufacturer.

KEYWORDS: Performance; balers; mobile; Pakistan.

INTRODUCTION

Wheat is one of major cereal crops of Pakistan covering an area of 21.4 million hectares during the year 2010 with a production of 19.20 million tons (1). The straw (bhoosa) production is equivalent to that of grains. Due to mixed crop-animal based farming system in Pakistan wheat straw is an important component of stock feed. The wheat straw is primarily used for stock feed, paper industry, packages and mud plaster for rural houses. It is used as a major source of feed for approximately 28 million animals and is mixed in various feeding materials i.e. green fodder, castor oil cake (khal), animal feed (wanda), etc.(4).

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The wheat is harvested manually or with reaper and is threshed with thresher separating grains from chopped straw. The handling of bhoosa is a serious problem due to its low density. The farmers generally store the bhoosa in mud plaster covered heaps right in the field called “Dharh” or low cost structures made of different kinds of dried crop wastes called “Palla”. The bhoosa stored in Dharh or Palla is not safe as rain water can enter into the heap through cracks developed in mud plaster and spoils the bhoosa. Moreover, bhoosa is spoiled by rats, animal attacks and weather. The mud structure used to store bhoosa also occupies some portion of field which cannot be used for crop production. Moreover, application of irrigation water reduces the quality of bhoosa stored in Dharh and Palla (10).

The bhoosa is used as animal feed. So its proper storage and handling is important to avoid its shortage during winter months. The inappropriate storage of bhoosa reduces its market value. Its transportation from field to storage area is laborious and costly. The overloading of bhoosa causes serious problem in travelling and sometimes accidents.

The baling facility in the field helps save the bhoosa from weather calamities, makes handling and transportation easier, facilitates its easy and safe storage and maintains its quality.

A baler is used to compress a cut and raked crop such as hay and straw into bales and bind them with twine. Round baler is frequently used. It produces cylindrically shaped ‘round’ or ‘roller’ bales. Early round balers were made by Allis Chalmers in 1947 as the rota baler. The baler made bales were roughly 406 mm in diameter and 1219 mm wide. The modern round baler was designed by Vermeer in 1972. The round bales made with this baler weighed upto one ton or more, and were well-suited to modern large scale dairy farm with 200 or more cows. It was power take-off operated and hay was manually fed. The biggest change to this type of baler occurred in 1940 when it was powered by the tractor, instead of a built-in internal combustion engine as reported by Curley *et al.*(2).

Smith and Wilkes (8) mentioned that most of the field balers were pull type, self-propelled machines that produced rectangular bales varying in size i.e. 406 to 457 mm in width, 813 to 1067 mm in length and weighed from 18 to 40 kg. Self propelled models provided better visibility and maneuverability, but required higher annual use to justify their higher capital cost. The rectangular baler gained some popularity on small-scale, low-mechanization agriculture. Square and rectangular bales were generally better than round bales because a denser stack was put up. The automatic baler for small

square bales was first manufactured by the New Holland in 1940 which was operated by a small petrol engine (9).

Smith *et al.* (7) described baler as a mechanical machine operated by a tractor power take off or an engine incorporated within the baler. It physically picked up the straw and placed it into a compression chamber. The straw in the compression chamber was compressed by hydraulic ram. The hydraulic pressure applied to a bale of straw varied from 136 to 170 kg/cm^2. Kepner *et al.* (5) described that hay was handled from the field as bales and densities of baled hay were generally varied from 130 to 225 kg/m^3 and hay was simply rolled up inside the baler with belt conveyors, fixed rollers, or a combination of rollers and belts. The current models of conventional field balers were automatic tieing machines with reciprocating plungers that produced bales with rectangular cross section. Rectangular bales were easier to transport than round bales since there was little risk of the bale rolling off the back of a flatbed trailer. The rectangular shape also saved space and allowed a complete solid slab of hay to be stacked up for transport (3).

The private sector in Pakistan have installed some stationary bhoosa baling units on road side in different areas and are normally far from the field and are comparatively lesser in number. The owners purchase bhoosa during threshing season at cheaper rates and transport it to baling sites. It is generally kept in open heap and later converted into bales and sold at higher rates. These stationary balers cannot be hired by the farmers or dairy owners. The purchase of bhoosa in bulk rather creates shortage in the market. Moreover, the common farmers cannot install these balers at their farms because of higher capital cost (10).

The stationary double cylinder straw balers are equipped with 50-80 hp (36.75-58.83 kW) diesel engine. The gear/plunger pumps are used to make bales of different sizes. The output of these balers varied from 45 to 55 bales per hour with 9 to 15 labourers required to perform this operation. The weight of straw bales ranged from 30 to 40 kg. The installation cost of baler ranged from 0.35 to 0.5 million rupees. The cost of land where stationary baler was installed ranged from Rs. 0.8 to 1.0 million. These balers were used for baling of wheat straw for supplying to industrial sector like paper industry, etc. as reported by Javed and Mughiz (4).

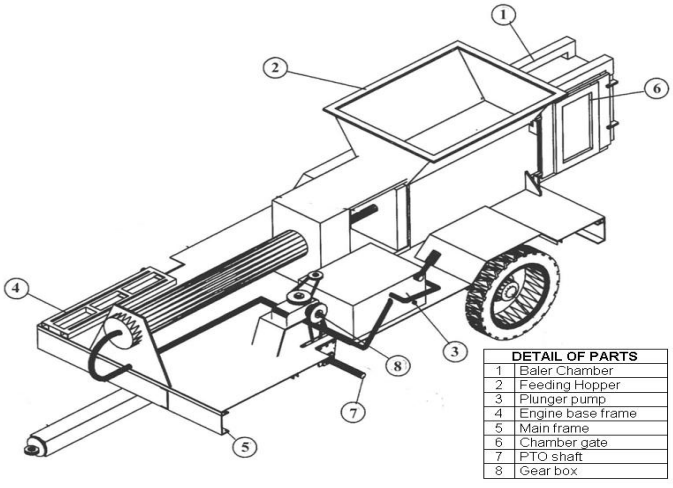
The availability of agricultural wastes/residues of major crops such as cotton stalks, bhoosa, rice straw, rice husk, sugarcane stripping, corn stovers and corn cobs pith were 5.49, 18.42, 3.64, 1.57, 4.02 and 0.068 million ton per year, respectively. The purchase price varied from Rs. 2500/- to 3500/- per

ton for bhoosa and Rs. 1200/- to 2000/- per ton for cotton stalks. The sale prices of rice straw, rice rusk, corn stovers, corn cob pitch and sugarcane stripping were approximately Rs. 2400, 5000, 1700, 5500 and 850 per ton, respectively as reported by Naeem and Yasin (6).

The present paper reports the performance and attributes of a mobile straw baler designed and developed to assist the farmers and dairy owners to bale bhoosa and other crop residuess at their farms and store them safely for stocks and other purposes.

MATERIALS AND METHODS

A mobile straw baler was designed and developed at Agricultural Mechanization Research Institute (AMRI), Multan, Pakistan during the year 2003 and modified during 2004 (Fig. 1) in view of the field results and farmers comments. In this study field performance of this baler was evaluated during the year 2009. The design parameters of this mobile straw baler were based on local farm size, crop wastes and field conditions. The first prototype of mobile straw baler was fabricated at AMRI's workshop in 2003 using locally available materials, fabrication techniques and facilities. Some of important components and parts such as hydraulic pump, hydraulic jack and gears were manufactured by the local industry according to their technical specifications.



DETAIL OF PARTS	
1	Baler Chamber
2	Feeding Hopper
3	Plunger pump
4	Engine base frame
5	Main frame
6	Chamber gate
7	PTO shaft
8	Gear box

Fig. 1. Sketch of mobile straw baler.

The baler is mounted on a small trolley which can be transported to threshing sites and bales are made right after threshing. It can be operated with a tractor pto (power taker off) or 20 hp diesel engine or 14 kW electric motor. The baler comprises a feeding hopper, a compressing chamber, a hydraulic jack, a hydraulic pump, a gear box, main frame and power drive system (Fig. 2). The overall length, width and height of baler are 5300 mm, 1610 mm and 2060 mm, respectively. The main frame is 2530 mm long and 1075 mm wide made from mild steel (M.S.) channel measuring 150 x 50 x 6 mm. The baling chamber and gear box supports are also made of M.S. channel and welded on main frame reinforced with brasses of M.S. plates.

Fig. 2. Mobile straw baler in operation in the field.

The hydraulic pump is driven by a gear box powered by a pto tractor shaft or diesel engine or electric motor. The pump hosing contains control valve assembly to operate hydraulic ram. A hydraulic pump with 36 plungers is capable of producing a maximum pressure of 272 kg/cm^2. The pump chamber is mounted on M.S. channel welded to the main frame. The pressure hose pipe of internal dia 19 mm and seamless pressure pipe of outer dia 25 mm are used for hydraulic fluid.

The bale chamber is made of M.S. plate of size 10 mm and is 2050 mm long, 300 mm wide and 425 mm high. The bhoosa or straw falls from feeding chute into the bale chamber and is held against the sliding compression plate of jack for compression. Two side doors and one top door reinforced with M.S. plates are fitted in the bale chamber. The appropriate door lock system is provided to lock the chamber during compression stroke. The bale chamber bottom plate is made of M.S. sheet of 18 mm thickness and reinforced with a thicker M.S. plate.

The feeding chute bolted at the top of compression chamber is used to feed bhoosa or straw manually into the compression chamber. The hydraulic jack of outer diameter 140 mm and 225 mm long compresses the bhoosa or straw against the stationary compression plate and converts it into a proper bale form.

RESULTS AND DISCUSSION

The mobile straw baler was tested in the field at different locations to make bales of various crop wastes (Fig. 3). A team of four person was required to operate, load straw, tie rope to bale and take out the bale from the chamber. The straw bales made with this baler were easy to make denser stack to weather better (Fig. 4). The baler is operated with 50 hp tractor or 20 hp diesel engine or 14 kW electric motor.

Fig. 3. Straw bales in stock form.

The baler made bales of size approximately 391 x 457.13 x 635 mm. The operation and handling of the bales was simple and easy. The loading and transportation of bales with truck and trolley was easy and cheaper than that of the straw (Fig. 5). The cost of baler is 3.5 to 4.0 lacs rupees. The average weight and volume of bhoosa bale were 34.6 kg and 113498 cm^3, respectively. The baler took 4.3 minutes and consumed 17 men-minutes to prepare a bale. The baler was tested on cotton sticks, corn stovers and sugarcane chaff. Through output of baler for bhoosa, cotton sticks, corn stovers and sugarcane chaff was 20, 16, 18 and 16 bales per hour, respectively. The cost per bale was calculated as Rs. 17, 10 and 38 with diesel engine, electric motor and tractor operation of baler, respectively. The work performance of the baler was found satisfactory and appreciated by the

Fig. 4. Loading of straw bales on truck for transportation.

Fig. 5. Different crop residues/wastes bales prepared with mobile straw baler

farmers. The prototype of baler was adopted by the local industries for its mass production and promotion in the field.

Wheat straw (bhoosa)

The mobile baler was tested on wheat straw to make bales and data for ten bales were recorded (Table 1). The average size of bhoosa bale was 391 x 457.13 x 635 mm. The average weight and volume of bale was 34.6 kg and 113498 cm^3, respectively. The baler took 4.3 minutes and required 17 men-min to prepare a bale. The average output of baler was 20 bales per hour. The cost per bale was calculated Rs. 17, 10 and 38 by operation of baler with diesel engine, electric motor and 50 hp tractor, respectively (Table 2).

Table 1. Weight and volume of bhoosa bale alongwith bale making time of mobile baler.

Weight of bale (kg)	Volume of bale (cm^3)	Time for bale making (minutes)	Man-min @ 4 men for operation
35.0	110613	4.5	18
34.2	117987	3.5	14
34.4	115959	4.5	18
34.8	109261	4.4	18
34.5	111433	4.3	17
34.7	104468	4.5	18
35.0	120347	4.5	18
34.6	123690	4.3	17
34.3	107541	4.0	16

	34.5	113686	4.3	17
Avg.	34.6	113498	4.3	17

Table 2. Operational cost of mobile straw baler.

Capital cost (P)	Rs.	35,0000/-
Annual use (AU)	hr	2400
Total life in year (L)	Year	10
Total life in hours (L)	hr	24000
Salvage value @ 10% of P (S)	Rs.	35000
Depreciation [(P–S) /L (hr)]	Rs/hr	13.12
Interest @ 10% of AU [(P–S) / 2 x 0.1/AU]	Rs/hr	8.02
Insurance, Shelter & Taxes @ 2% of [(P+S) / /AU]	Rs/hr	1.6
Repair & maintenance @ 15% of P/L(hr)	Rs/hr	2.18
Number of labours	No.	4
Labour cost @ 6000 Rs/month/person (8 hrs per day)	Rs/hr	100
Diesel engine @ 60 Rs / Petter (3 litre/hr)	Rs.	180
Lubricant @ 15% of fuel cost	Rs.	27
Electric motor 14 kW	Rs/hr	84
Output bundles / hr	Bundles/hr	20
Cost of operation with diesel	Rs/hr	332
Cost of operation with electric motor	Rs/hr	209
Cost of operation with rented tractor (@ 950 Rs/hr hiring rate)	Rs/hr	1075
Cost of operation with own tractor (50 hp tractor) (20 year life, AU = 500 hrs)	Rs/hr	766
Cost of operation with diesel engine	Rs/bundle	17
Cost of operation with electric motor	Rs/bundle	10
Cost of operation with rented tractor	Rs/bundle	54
Cost of operation with own tractor	Rs/bundle	38

Other crop wastes

Performance of baler was also tested on other crop wastes such as cotton sticks, corn stovers and sugarcane chuff (Table 3). The cotton sticks and corn stovers bale size was 685.8 x 457.2 x 660.4 mm and 685.8 x 457.2 x 457.2 mm, respectively with average weight of 44.2 kg and 35.4 kg, respectively. The average weight and volume of bales was calculated as 44.2 kg and 207068 cm^3 for cotton sticks 35.4 kg and 143354 cm^3 for corn stovers, respectively. The shedding time for cotton sticks and corn stovers was measured 9.7 and 6.3 minutes, respectively. The baling time for cotton sticks and corn stovers was noted as 5.7 and 5.0 minutes, respectively. The men-minutes required to make bales were estimated at 23 and 20 for cotton sticks and corn stovers, respectively. The bale prepared from sugarcane chaff was of 685.8 x 457.2 x 482.6 mm size. The weight and volume of bale was calculated as 44.6 kg and 151319 cm^3 with baling time of 12.3 minutes.

The output of baler for cotton sticks, corn stovers and sugarcane chaff was determined as 16, 18 and 16, respectively.

Table 3. Baler performance for making bales of different crop wastes

Crop wastes	Weight (kg)	Shredding time (minutes)	Time for bale making (minutes)	Volume of bale (cm3)	Man-min @ 4 men for operation
Cotton sticks	45	9.2	5.4	207068	21.6
	43	9.4	5.6	207068	22.4
	45	10	6.3	207068	25.2
	44	10.2	6	207068	24
	44	9.6	5.5	207068	22
Average	44.2	9.68	5.76	207068	23.04
Corn Stovers	36	6	4.6	143354	18.4
	36	5.6	4.8	143354	19.2
	35	7	5	143354	20
	35	6.5	5.2	143354	20.8
	35	6.4	5.4	143354	21.6
Average	35.4	6.3	5	143354	20
Sugarcane Chaff/ Khori	34	0	12	151319	48
	35	0	11.5	151319	46
	35	0	13	151319	52
	35	0	12.5	151319	50
	84	0	12.7	151319	50.8
Average	44.6	0	12.34	151319	49.36

CONCLUSION

This study concludes that mobile straw baler is helpful for farmers and dairy owners in making bales of straw and bhoosa for easy handling, transportation and safe storage. Overall, the baler performance was satisfactory and appreciated by the farmers and dairy owners. Thus straw baler was adopted by the local industry for its mass production and promotion.

RECOMMENDATION

The performance and utlity of this mobile straw baler can be improved by converting its horizontal compressing unit into vertical compressing unit alongwith fitting of more efficient hydraulic pump having less plungers.

REFERENCES

1. Anon. 2010. Economic Survey, Economic Advisor's Wing, Finance Division, Government of Pakistan, Islamabad.

2. Curley, R.G., J.B. Dobie and P.S. Parrons. 1973. Comparison of Stationary and Field Curbing of Forage. Trans. of ASAE USA. 16(2): 361-364, 366.
3. Hunt, D. 1995. Farm Power and Machinery Management, 9th Ed. Iowa State University Press AMES. USA.
4. Javed, I. and A. Mughiz, 2009. Wheat Straw Pulping - an Expert Opinion. One day workshop. Cleaner Production Institute, Industrial Sustainable Development. Hotel Sunfort, Lahore.
5. Kepner, R.A., R. Bainer and E. L. Barage. 1987. Principles of Farm Machinery. Third Edition. The AVI Pbulishing Company, INC. Westport, Connecticut, USA.
6. Naeem, H.M. and M. Yasin. 2011. Agricultural wastes of major crops to use for power generation in Punjab. Pesented at Farm Mechanization and Power Week on the eve of Golden Jubilee Celebration at University of Agriculture, Faisalabad.
7. Smith, B. R., J. Howard and P. Hansen. 2002. The Manufacturing Process of Straw Particle Board. An introduction. Washington State University Report.
8. Smith, H.P. and L.H. Wilkes. 1976. Farm Machinery and Equipment - 6th Edition. McGrew-Hill Book Company, New York, U.S.A.
9. Smith, H.P. and L.H. Wilkes. 1990. Farm Machinery and Equipment. McGraw-Hill Book Company, New York, U.S.A.
10. Yasin, M. 2009. Modern Method to Store Wheat Straw Bhoosa (Urdu) Ziraat Nama. April issue. Directorate of Agricultural Information, Government of Punjab, Agriculture House, Lahore.